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(54) **Method and device for reducing the transmission power on a digital subscriber line**

Verfahren und Vorrichtung zur Reduzierung der Sendeleistung auf einer digitalen Teilnehmerleitung

Procédé et dispositif pour la réduction de la puissance d'émission sur une ligne d'abonné numérique

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- **MUTA O ET AL: "A Peak Power Reduction Scheme Based on Reversal of Parity-bits for a Block-coded OFDM Signal" VEHICULAR TECHNOLOGY CONFERENCE, 2004. VTC 2004-SPRING. 2004 IEEE 59TH MILAN, ITALY 17-19 MAY 2004, PISCATAWAY, NJ, USA,IEEE, US, vol. 4, 17 May 2004 (2004-05-17), pages 1911-1915, XP010766494 ISBN: 978-0-7803-8255-8**

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EP 2 150 010 B1

Description

[0001] The invention relates to a method and to a device for data processing and to a communication system comprising such a device.

[0002] The evolution of DSL technology is characterized by achieving higher bit-rates by broadening of the transmission bandwidth. Since both loop attenuation and crosstalk are increasing with frequency more sophisticated measures are necessary to be provided at the DSL transmitter and the DSL receiver.

[0003] Currently deployed VDSL2 systems already use bandwidth up to 17Mhz, while the ITU-993.2 standard suggests a bandwidth of up to 30Mhz. A typical target bit rate of, e.g., 100Mbit/sec (amounting to a bidirectional net data rate of 200Mbit/sec) at a loop length of 0.8km to 1km cannot be achieved by current transceiver technology. Crosstalk reduction leads to an increase of reach (maximum admissible loop length at a given rate) or an increase of data rate (at given loop length) or it may result in an increased stability of a "living loop plant" situation (i.e. CPEs turned off and on causing fluctuating crosstalk).

[0004] In terms of cost required for implementation, approaches to efficiently reduce crosstalk also decrease transmission power that is the basis for any interference. An example is the so-called power back-off (according to ITU-993.2 standardized for VDSL2) which reduces a power of a user with relatively short loop length in a temporally stationary way. Another possibility of reducing an average (transmission) power is avoiding the transmission of idle bits (i.e. avoiding a status quo that maintains a bit rate over the DSL link even when no actual user data is transmitted - "leased line philosophy"). Such a low power mode is standardized in the context of ADSL2/ADSL2+, referred to as a "L2-mode", which is based upon a handshake-based negotiation between a transmitter and a receiver (according to ITU-992.3 and ITU-992.5). Such handshake-based procedure is relatively slow and may lead to interoperability issues. In addition, operators and service providers believe in problems due to fluctuating crosstalk.

[0005] US 2006/120269 A1 refers to a transmitting apparatus of an OFDM system.

[0006] [Muta el al.: "A Peak Power Scheme Based on Reversal of Parity-bits for a Block-coded OFDM Signal", Vehicular Technology Conference, IEEE, Vol.4, 17.05.2004, pages 1911-1915, ISBN: 978-0-7803-8255-8] discloses a peak power reduction scheme based on reversal of parity-bits for a block-coded OFDM signal.

[0007] According to WO 2005/034459 frequent changes in transmission power enable non-coherent crosstalk estimation methods. However, a central management entity may register changes in the transmit power as well as changes in a receiver's signal-to-noise-ratio (SNR). A binary correlation analysis may provide a non-coherent (in particular regarding a magnitude) information about crosstalk-couplings between different DSL ports.

[0008] **Fig.1** shows a traffic simulation assuming three high-definition IPTV channels providing a stationary floor of about 40Mbit/sec and typical bursts of IP traffic resulting from web browsing applications with peak data rates of more than 100Mbit/sec.

[0009] The **problem** to be solved is to overcome the disadvantages mentioned above and in particular to provide an efficient approach of saving cost and energy in particular in a DSL environment.

[0010] This problem is solved according to the features of the independent claims. Further embodiments result from the depending claims.

[0011] In order to overcome this problem, a method is provided for data processing via a digital subscriber line comprising the steps of claim 1.

[0012] It is noted that digital subscriber line applies to all existing and upcoming technologies standards, comprising, e.g., xDSLn, wherein x stands for "A", "V", and n may be "1", "2", "2+", etc.

[0013] The approach provided allows for an efficient bit manipulation of a data stream to be transmitted in a way that it requires a reduced amount of energy. This concept is in particular applicable with a leased line philosophy that conveys idle data even in cases when no user data is to be transferred. Such idle data (or portions thereof) are manipulated in a way that they require less energy to be transmitted. Another advantage of this approach is that such manipulated data inflicts less crosstalk thereby allowing a higher bitrate (or less power provided) for data that actual carries user information.

[0014] It is noted that at a particular transmission stage, the bits may arrive in a scrambled fashion. The processing unit that copes with such sequence of "0" and "1" may be not aware of which "0" and "1" belongs to idle data, user data or (useful) overhead data. Hence, the approach suggested manipulates at least a portion of such data (preferably on a bit-by-bit level in an iterative manner) and further assesses whether such change has a detrimental impact on the user data. If this is not the case, i.e. if the user data do not deteriorate (beyond a predetermined degree), the manipulation is deemed applicable and the manipulated data may be transferred or transmitted to a receiver.

[0015] In a multiuser scenario, bursts of IP traffic may be handled by statistically multiplexing means allowing for an aggregation ratio of up to 1:50 without any significant degradation of performance. It is an advantage of cross-layer-modulation (CLM) to exploit this multiplexing gain due to the bursty IP traffic. In addition, high rates of data traffic (peaks) enable powerful retransmission methods that allow dealing with an impulse noise problem, which is currently one of the obstacles of widespread IPTV adoption particularly for carriers with inhouse cabling of poor quality.

[0016] The approach provided is in particular applicable in low latency configurations (so-called "fast path" scenario

without forward-error correction and interleaver), wherein any tone-ordering may be switched off. This prerequisite in particular fits into the "burst transmission" scenario rather than "leased line philosophy".

[0017] In an embodiment, steps (a) and (b) are repeatedly processed for a data frame, in particular for a DMT frame.

[0018] In another embodiment, after step (a) it is checked whether the manipulation leads to a reduced transmission power.

[0019] In a further embodiment, the at least one bit of the data is manipulated by flipping at least one bit's value.

[0020] In a next embodiment, in step (b) it is checked by a descrambler whether the manipulation of step (a) leads to bit errors regarding in particular payload data and/or necessary overhead data.

[0021] It is noted that a particular degree of error may be admissible as well (and may advantageously be corrected by error handling or error correction means).

[0022] It is also an embodiment that the descrambler comprises a reduced amount of taps compared to a scrambler.

[0023] Pursuant to another embodiment, in a step (d) the manipulation is not executed (as the manipulation is deemed inadmissible) and it is in particular branched to step (a).

[0024] According to an embodiment, prior to step (a) a scrambler provides said data to be processed.

[0025] Such data may in particular comprise overhead data, payload data and idle data. The amount of idle data may depend on the actual user traffic conveyed via the line(s).

[0026] According to another embodiment, a bit mask is applied at the scrambler's input. It may be checked whether the manipulation is admissible by checking whether the manipulated at least one bit of data does not fall into the bit mask.

[0027] In yet another embodiment, manipulated data is transmitted in upstream and/or in downstream direction.

[0028] According to a next embodiment, the method is provided or associated with a transmitting stage in a central office and/or a digital subscriber line access multiplexer and/or a customer premises equipment.

[0029] The problem stated above is also solved by a device comprising a and/or being associated with a processor unit and/or a hard-wired circuit and/or a logic device that is arranged such that the method as described herein is executable on said processor unit.

[0030] According to an embodiment, the device is a communication device, in particular a or being associated with a central office or digital subscriber line access multiplexer or a customer premises equipment.

[0031] The problem stated supra is further solved by a communication system comprising the device as described herein.

[0032] Embodiments of the invention are shown and illustrated in the following figures:

Fig.2 shows a schematics of a scrambler;

Fig.3 shows a schematics of a descrambler for decoding data encoded by the scrambler according to Fig.2;

Fig.4 shows a diagram comprising steps of a binary precoding scheme that can be efficiently applied to reduce either crosstalk and/or (transmission) power;

Fig.5 shows a more detailed version of the binary precoding scheme according to Fig.4.

[0033] The approach provided herein allows for cross-layer modulation-based rate-adaptive power reduction.

[0034] The principle of cross-layer modulation (CLM) can be summarized, e.g., as follows: A transmitter located at or associated with a central office (CO) sends idle cells (ATM) or idle frames (Ethernet). The data pattern is adapted to a specific bit loading vector and to a respective QAM mapping, i.e., bit combinations are selected that are close to the origin of the complex plane and thus require a reduced amount of power when being transmitted. Such bit combination may constitute or be part of "power shaping" packets.

[0035] User bits, bits with VDSL2 overhead information and certain parts of the Ethernet frame and/or ATM are preferably excluded from such power shaping in order to avoid additional bit errors. With user traffic decreasing, such "power shaping" packets can increasingly be inserted, which in turn leads to a significant power reduction.

[0036] The approach provided is applicable in upstream direction and/or in downstream direction.

[0037] Overhead bits may in particular comprise any mixture of payload and actual overhead information. CLM may preferably treat payload and actual overhead information in a same manner and may not distinguish between both.

[0038] **Fig.2** shows a scrambler schematics with an input IN fed to an XOR operator 201. An output OUT of the XOR operator 201 is connected to a shift register 203 comprising 23 stages, wherein stage 18 and 23 are combined by an XOR operator 202, which output is further fed to said XOR operator 201. The scrambler of Fig.2 can be understood as a linear time-invariant system acting over a Galois field F2 having an impulse response of infinite length.

[0039] The approach presented herein overcomes a mixing effect of the scrambler by a fixed-length iterative coding procedure.

[0040] **Fig.3** shows a descrambler schematics. An input IN is fed to a shift register 301 comprising 23 stages. The

input IN is further connected to an XOR operator 302 which output provides an output signal OUT. Stage 18 and stage 23 of the shift register 301 are combined by an XOR operator 303. The output of said XOR operator 303 is fed to the XOR operator 302.

[0041] As VDSL2 uses an adaptive multicarrier QAM modulation in the sense that the number of bits modulated onto each carrier varies with the carrier index (bit numbers q admissible usually vary as follows: $1 < q < 15$). A mapping between bits and complex numbers Q(b), i.e., for a given binary vector of varying length Q(b), is a complex number (out of a finite alphabet as set forth in ITU-992.3).

[0042] The approach is inserted preferably immediately before a scrambling stage at the transmitter side. Preferably, a complete bitloading vector for one DMT frame (in VDSL2 this may in a worst case scenario amount to a memory of 4KByte) is buffered.

[0043] A bit mask is suggested for the overhead bits (at the scrambler's input):

$$\kappa_{OH}(k) = \begin{cases} 1, & \text{if bit with index for } k \text{ is overhead bit} \\ 0, & \text{if not} \end{cases} \qquad (1).$$

[0044] Hence, the (complete) bitloading vector is initialized with overhead bits and with random bits from a (e.g., fairly arbitrary) random number generator.

[0045] Preferably, each of the scrambled bits is then checked whether flipping the value of the n-th bit decreases the power level:

$$|Q(Sb + \delta_n)| < |Q(Sb)| \qquad (2).$$

[0046] It is noted that such flipping of a bit can be summarized as adding a number "1" via binary field F_2 addition (corresponding to an exclusive-or (XOR) operation in computer algebra). $\delta(n)$ is referred to as the Kronecker delta, wherein

$$\delta(n) = \begin{cases} 1, & \text{if } n = 0 \\ 0, & \text{if } n \neq 0 \end{cases} .$$

[0047] If the condition (2) is true, it is checked whether changing this bit is admissible or not.

[0048] The descrambler may be provided with a limited (finite) memory having n impulse response as follows:

$$h(n) = \delta(n) + \delta(n - 18) + \delta(n - 23) \qquad (3)$$

[0049] Hence, due to the scrambler's structure (see Fig.2), flipping one bit at the scrambler's output may flip three bits the scrambler's input.

[0050] It is preferably checked whether these three bits affected do not fall into the bit mask for the overhead bits:

$$\kappa_{OH}(n) \cdot (\delta(n) + \delta(n - 18) + \delta(n - 23)) = 0 \qquad \forall n \qquad (4).$$

[0051] If equation (2) and equation (4) are satisfied, the n-th bit can be flipped and such flipping results in a reduction of power.

[0052] After having processed these steps for the scrambled bitloading vector, the modified bits can be inserted to further processing stages, e.g., a mapper, a IFFT, etc. Then the steps can be applied to a subsequent DMT frame.

[0053] The steps of this approach are schematically summarized in Fig.4 and in Fig.5.

[0054] **Fig.4** shows a diagram comprising steps of a binary precoding scheme. Such precoding scheme can be efficiently applied to reduce either crosstalk and/or power.

[0055] An overhead channel 401 and a pseudo-random number generator (PRNG) 402 are both fed to a stage 403 which generates a DMT frame, i.e. an unscrambled bitstream b by combining overhead bits b_{OH} and random bits B_{RAND}:

$$b = b_{OH} + b_{RAND} \quad (5).$$

[0056] The bitstream b is further fed to a scrambler 404 that produces a scrambled bitstream Sb and conveys it to a processing stage 405.

[0057] The processing stage 405 checks how the bitstream Sb may be modified to allow for a lower transmission power according to:

$$|QAM(Sb \oplus \delta_n)| < |QAM(Sb)| \quad (6),$$

wherein δ_n references a dirac impulse.

[0058] Prior to entering processing stage 405, a loop index n is set to 0. Furthermore, a bitloading vector b_{vector} is provided.

[0059] If the condition according to equation (6) is true, a processing stage 406 is entered. The processing stage 406 checks whether the modification determined is admissible:

$$\sum[\kappa_{OH} \otimes (\delta_n + \delta_{n-18} + \delta_{n-23})] = 0 \quad (7),$$

wherein κ_{OH} states an overhead mask.

[0060] If the condition according to equation (7) is true, a processing stage 407 is entered constituting the scrambled bitstream Sb according to:

$$Sb \Leftarrow (Sb \oplus \delta_n) \quad (8).$$

[0061] In a subsequent step 408, it is checked whether the loop index n has reached the frame length F_{len}. If this is true it is branched to a step 409 sending the shaped frame comprising the scrambled bitstream Sb. If this is not true, the loop index n is incremented (n=n+1) and it is branched to processing stage 405.

[0062] If either equation (6) or equation (7) is false, it is branched to step 408.

[0063] **Fig.5** is a more detailed version of the binary precoding scheme according to Fig.4.

[0064] Preferably, no multiplication needs to be performed. The most complex operation may be the QAM mapping according to equation (2), which can be implemented via iteration and table lookup.

[0065] The precoding approach can be used to approximate fairly arbitrary waveforms by replacing the amplitude criterion in equation (2) with an alternative criterion:

$$|Q_{opt} - Q(Sb + \delta_n)| < |Q_{opt} - Q(Sb)| \quad (9).$$

wherein Q_{opt} denotes an (substantially) arbitrary complex number. An example may be a downstream precoding in a multiuser environment, wherein Q_{opt} is selected in order to reduce or minimize crosstalk effects on (all) other lines.

Automatic Gain Control (AGC):

[0066] Another issue relates to an (undesired) adaptation of the automatic gain control (AGC) at the CPE. AGC is in particular relevant for an analog frontend of any receiver in digital communications. AGC in particular comprises a mixed-signal adaptation based on a continuous registration of a received signal thereby adjusting the analog receiver gain. This can advantageously be utilized to allow for an adaptation to a varying signal attenuation (depending on, e.g., loop conditions as loop length, copper diameter as well as on dielectric parameters).

[0067] If cross-layer modulation is applied, a legacy VDSL2 CPE may undesirably adapt to the lower transmit power: Hence, if the CO returns to higher transmit power this will result in a detrimentally high clipping rate at an A/D-conversion stage.

[0068] This issue can be resolved by utilizing a time duration of the power measurement thereby sending high power frames at a (more or less) regular time interval. Such high power frames may be conveyed in particular by the CPE.

Further Advantages:

[0069] The approach provided in particular suggests a novel binary precoding procedure enabling cross-layer modulation that can be supported by current transceiver technology.

[0070] The advantages of CLM compared to legacy DSL-technology can be summarized as follows:

(a) By lowering the average transmit power without handshake crosstalk can be reduced without any necessity for a firmware/hardware upgrade at the CPE side.

(b) By achieving higher instantaneous transmit power (without offending standardized PSD masks) CLM achieves a significant gain in reach.

(c) By providing a higher downstream peak date rate, CLM enables an approach for retransmission via the physical layer to efficiently reduce impulse noise (rather than adding redundancy for classical forward error correction schemes such as Reed-Solomon coding). Moreover, by temporally pooling the data rate (in a quasi burst mode fashion) the impact of impulse noise can be statistically reduced.

(d) CLM may utilize Ethernet aggregation technology [IEEE8023], but it can also be used for legacy ATM equipment.

List of Abbreviations:

[0071]

A/D	Analog to Digital
AGC	Adaptive Gain Control
CDMA	Code-Division Multiple Access
CLM	Cross-Layer Modulation
CO	Central Office
CPE	Customer Premises Equipment
DMT	Discrete Multi-Tone
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Module
DSM	Dynamic Spectrum Management
FDMA	Frequency-division Multiple Access
FFT	Fast-Fourier Transformation
FTTC	Fiber-To-The-Curb
IFFT	Inverse Fast-Fourier Transformation
NEXT	Near-End cross talk
PRNG	Pseudo-Random Number Generator
PSD	Power Spectrum Density
QAM	Quadrature Amplitude Modulation
SIR	Signal-to-Interference Ratio
SNR	Signal-to-Noise Ratio
TDMA	Time-division Multiple Access
XOR	Exclusive OR

Claims

1. A method for reducing energy required for data being transmitted via a digital subscriber line comprising the step of:

providing the data by a scrambler (404), the data comprising idle data together with overhead data and/or user data, the method being **characterized by**:

- manipulating (405) the data by flipping the value of at least one bit of the data such that the data requires less energy for transmission;
- checking (406) whether the manipulation leads to bit errors in overhead data and/or user data; and
- transmitting (409) the manipulated data if the manipulation does not lead to errors and transmitting the

unmanipulated data if the manipulation leads to errors.

2. The method according to claim 1, wherein steps of manipulating the data and of checking the manipulation are repeatedly processed for a data frame.

3. The method according to any of the preceding claims, further comprising the step of checking whether the manipulation leads to a reduced transmission power.

4. The method according to any of the preceding claims, wherein the step of checking whether the manipulation leads to bit errors is performed by a descrambler.

5. The method according to claim 4, wherein the descrambler comprises a reduced amount of taps compared to a scrambler.

6. The method according to any of the preceding claims, wherein a bit mask is applied at the scrambler's input.

7. The method according to claim 6, wherein it is checked whether the manipulation leads to bit errors by checking whether the manipulated at least one bit of data falls into the bit mask.

8. The method according to any of the preceding claims, wherein manipulated data is transmitted in upstream and/or in downstream direction.

9. A device comprising means arranged to perform all of the method steps according to any of the preceding claims.

10. The device according to claim 9, wherein said device is a central office, a digital subscriber line access multiplexer or a customer premises equipment.

11. Communication system comprising the device according to any of claims 9 or 10.

Patentansprüche

1. Verfahren zum Verringern der Energie, die erforderlich ist, um Daten über eine digitale Teilnehmeranschlussleitung zu übertragen, das den folgenden Schritt umfasst:

   Bereitstellen der Daten durch ein Verschlüsselungsgerät (404), wobei die Daten Leerdaten zusammen mit "Overhead"-Daten und/oder Anwenderdaten umfassen, wobei das Verfahren **gekennzeichnet ist durch**:

   - Manipulieren (405) der Daten **durch** Umkehren des Wertes von mindestens einem Bit der Daten, so dass die Daten für die Übertragung weniger Energie erfordern;
   - Überprüfen (406), ob die Manipulation zu Bit-Fehlern in den "Overhead"-Daten und/oder Anwenderdaten führt; und
   - Übertragen (409) der manipulierten Daten, wenn die Manipulation nicht zu Fehlern führt und Übertragen der nicht manipulierten Daten, wenn die Manipulation zu Fehlern führt.

2. Verfahren nach Anspruch 1, wobei die Schritte des Manipulierens der Daten und des Überprüfens der Manipulation für einen Datenrahmen wiederholt ausgeführt werden.

3. Verfahren nach einem der vorhergehenden Ansprüche, das ferner den Schritt des Überprüfens, ob die Manipulation zu einer verringerten Übertragungsleistung führt, umfasst.

4. Verfahren nach einem der vorhergehenden Ansprüche, wobei der Schritt des Überprüfens, ob die Manipulation zu Bit-Fehlern führt, von einem Entschlüsselungsgerät durchgeführt wird.

5. Verfahren nach Anspruch 4, wobei das Entschlüsselungsgerät im Vergleich mit einem Verschlüsselungsgerät eine geringere Menge von Registerkarten umfasst.

6. Verfahren nach einem der vorhergehenden Ansprüche, wobei eine Bit-Maske auf die Eingabe des Verschlüsse-

lungsgerätes angewendet wird.

7. Verfahren nach Anspruch 6, wobei überprüft wird, ob die Manipulation zu Bit-Fehlern führt, durch Überprüfen, ob das mindestens eine manipulierte Bit der Daten in die Bit-Maske fällt.

8. Verfahren nach einem der vorhergehenden Ansprüche, wobei die manipulierten Daten in vorgeschalteter und/oder in nachgeschalteter Richtung übertragen werden.

9. Vorrichtung, die Mittel umfasst, die dafür ausgelegt sind, alle Schritte des Verfahrens nach einem der vorherigen Ansprüche durchzuführen.

10. Vorrichtung nach Anspruch 9, wobei die Vorrichtung einer Zentrale, einem digitalen Teilnehmeranschlussleitungs-Zugriffsmultiplexer oder einem Teilnehmerstandortgerät entspricht.

11. Kommunikationssystem, das die Vorrichtung nach einem der Ansprüche 9 oder 10 umfasst.

Revendications

1. Procédé pour réduire l'énergie nécessaire à l'émission de données par l'intermédiaire d'une ligne d'abonné numérique, comprenant l'étape consistant à :

   fournir les données au moyen d'un embrouilleur (404), les données comprenant des données d'inactivité accompagnées de données de surdébit et/ou de données d'utilisateur, le procédé étant **caractérisé en ce qu'**il comprend les étapes consistant à :

   - manipuler (405) les données en inversant la valeur d'au moins un bit des données, de telle façon que l'émission des données nécessite moins d'énergie ;
   - vérifier (406) si la manipulation conduit à des erreurs de bits dans les données de surdébit et/ou les données d'utilisateur ; et
   - émettre (409) les données manipulées si la manipulation ne produit pas d'erreur et émettre les données non manipulées si la manipulation produit des erreurs.

2. Procédé selon la revendication 1, dans lequel les étapes de manipulation des données et de vérification des données sont traitées de façon répétitive pour une trame de données.

3. Procédé selon l'une quelconque des revendications précédentes, comprenant également l'étape consistant à vérifier si la manipulation produit une diminution de la puissance d'émission.

4. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'étape consistant à vérifier si la manipulation produit des erreurs de bits est effectuée par un désembrouilleur.

5. Procédé selon la revendication 4, dans lequel le désembrouilleur possède un plus petit nombre de prises que n'en possède un embrouilleur.

6. Procédé selon l'une quelconque des revendications précédentes, dans lequel un masque de bits est appliqué à l'entrée de l'embrouilleur.

7. Procédé selon la revendication 6, dans lequel on vérifie si la manipulation produit des erreurs de bits en vérifiant si ledit au moins un bit de données manipulé tombe dans le masque de bits.

8. Procédé selon l'une quelconque des revendications précédentes, dans lequel les données manipulées sont émises vers l'amont et/ou vers l'aval.

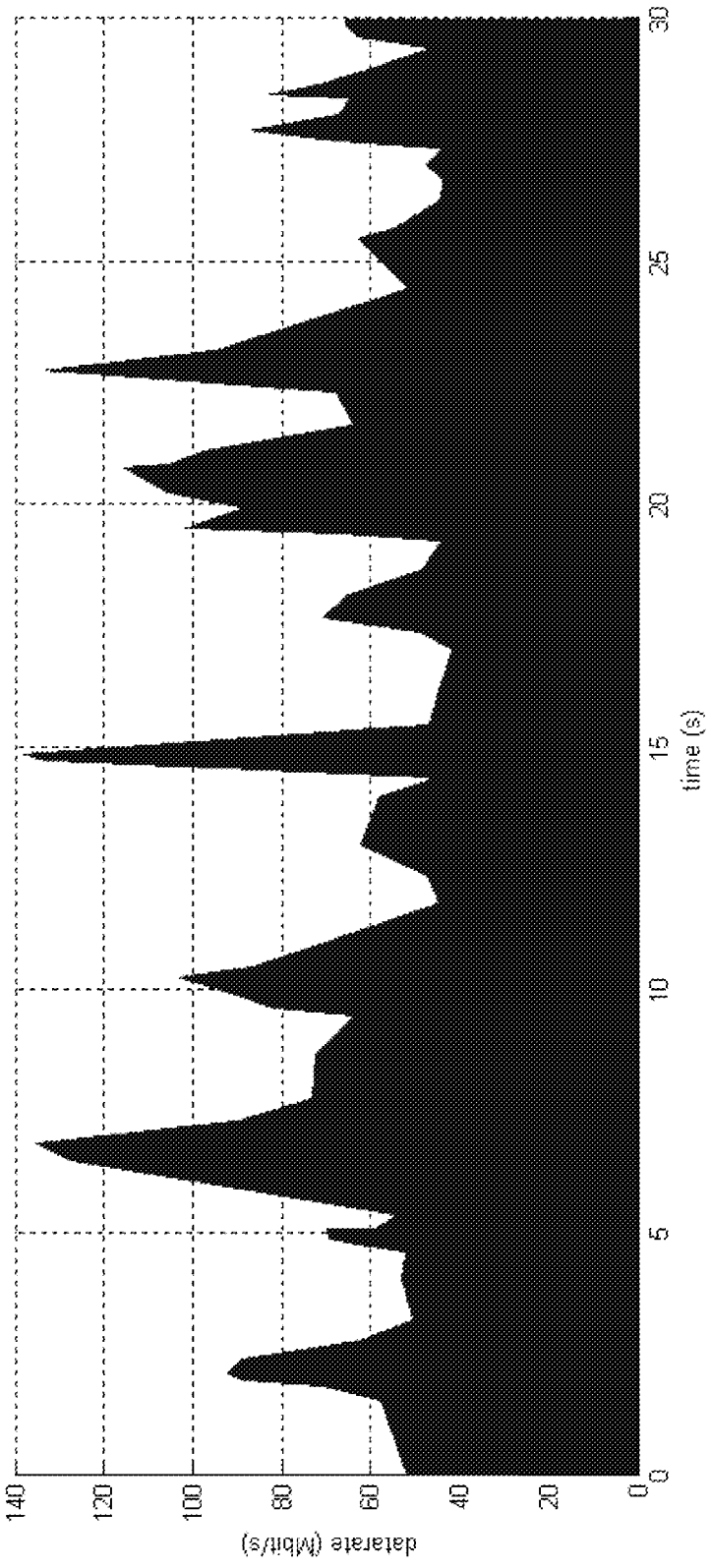
9. Dispositif comprenant des moyens agencés pour effectuer toutes les étapes de procédé selon n'importe lesquelles des revendications précédentes.

10. Dispositif selon la revendication 9, ledit dispositif étant un central, un multiplexeur d'accès à une ligne d'abonné

numérique ou un équipement des locaux d'abonné.

11. Système de communication comprenant le dispositif selon les revendications 9 ou 10.

Fig.1



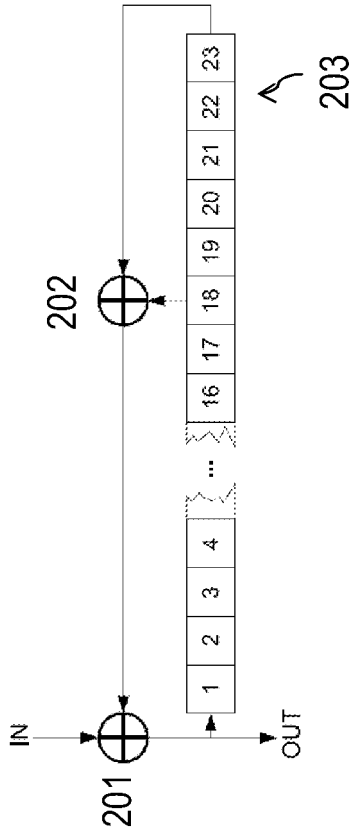


Fig.2

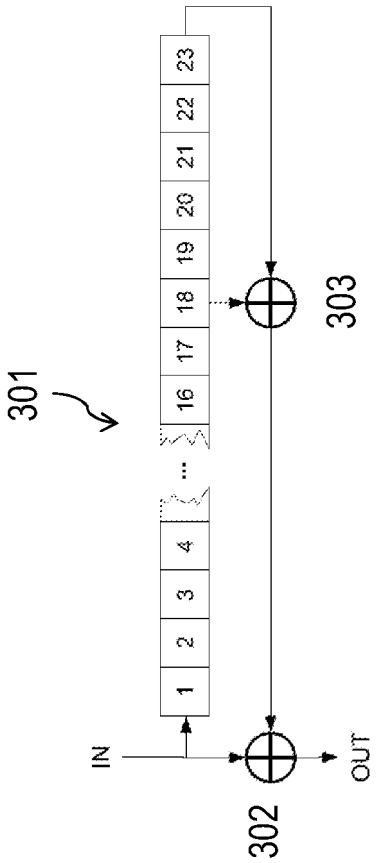
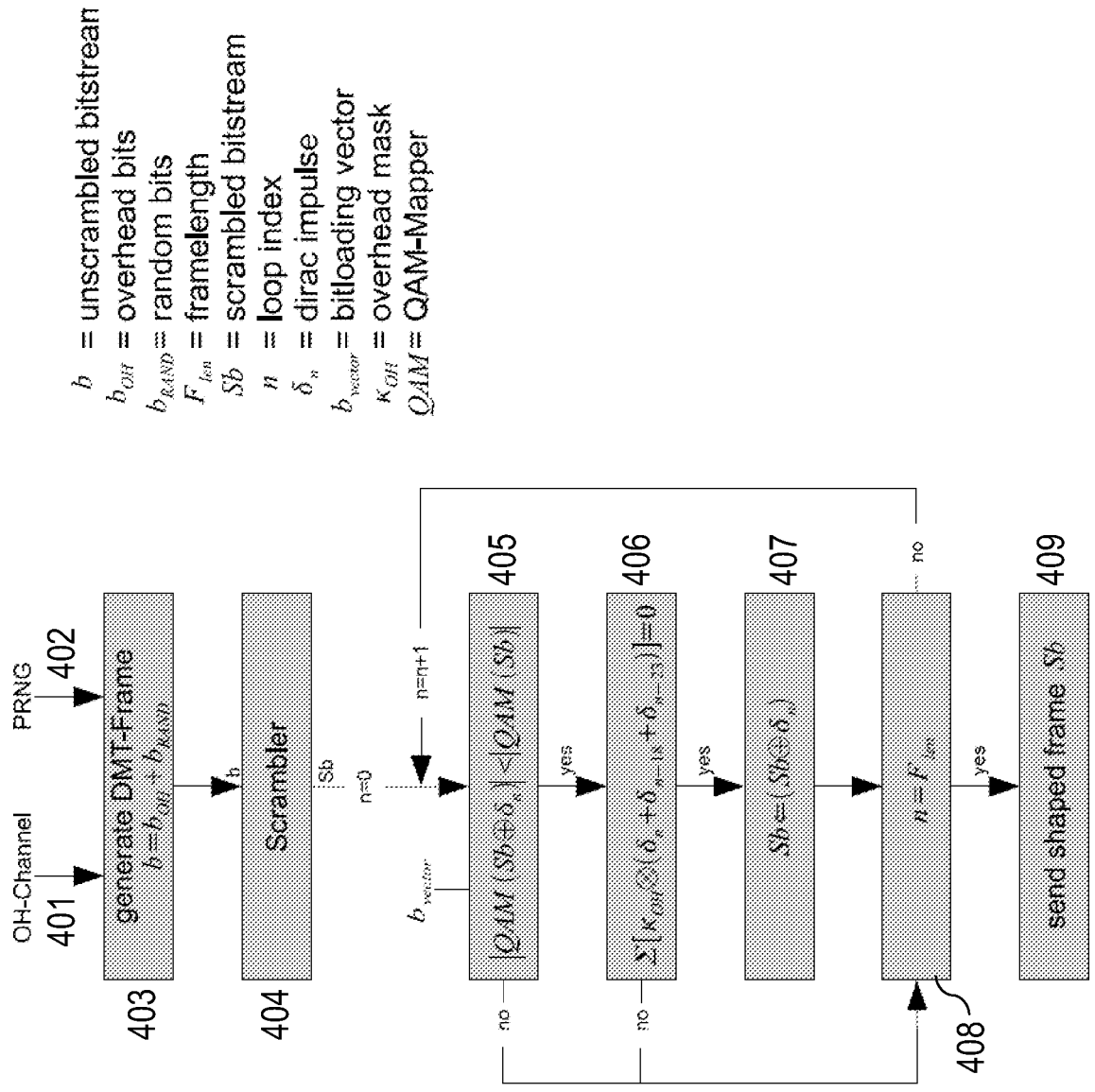


Fig.3

Fig.4


b = unscrambled bitstream
b_OH = overhead bits
b_RAND = random bits
F_len = framelength
Sb = scrambled bitstream
n = loop index
δ_n = dirac impulse
b_vector = bitloading vector
κ_OH = overhead mask
QAM = QAM-Mapper
OH-Channel
401
PRNG
402
generate DMT-Frame
b = b_OH + b_RAND
403
b
Scrambler
404
Sb
n=0
n=n+1
b_vector
|QAM(Sb+δ_n)|<|QAM(Sb)|
405
yes
no
Σ[κ_OH(n)(δ_n+δ_n-1N+δ_n-2N)]=0
406
yes
no
Sb=(Sb⊕δ_n)
407
yes
n=F_len
no
408
send shaped frame Sb
409

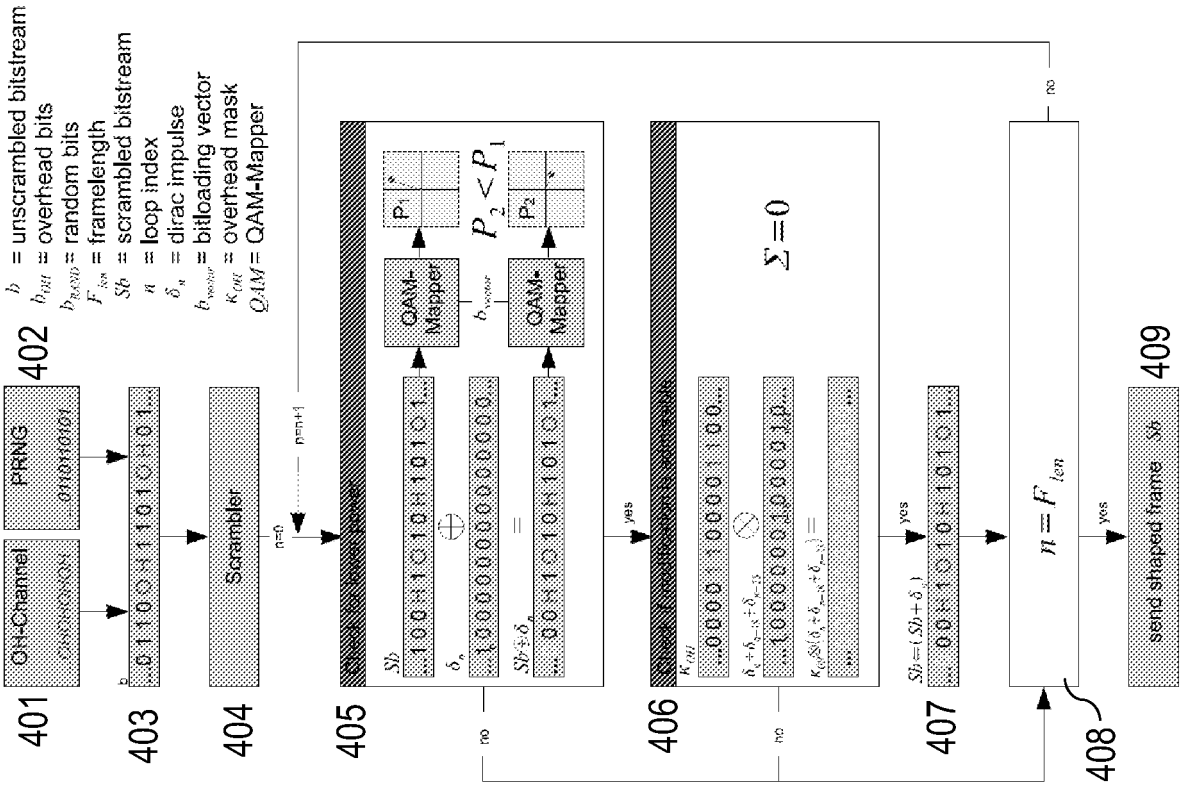

b = unscrambled bitstream
b_{OH} = overhead bits
b_{RAND} = random bits
F_{len} = framelength
Sb = scrambled bitstream
n = loop index
δ_n = dirac impulse
b_{vector} = bitloading vector
κ_{OH} = overhead mask
QAM = QAM-Mapper
401
OH-Channel
PRNG
402
403
404
Scrambler
405
QAM-Mapper
$P_2 < P_1$
406
$\Sigma = 0$
407
$n = F_{len}$
408
send shaped frame Sb
409
n=0
n=n+1
no
yes

Fig.5

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 2006120269 A1 **[0005]**
- WO 2005034459 A **[0007]**

Non-patent literature cited in the description

- A Peak Power Scheme Based on Reversal of Parity-bits for a Block-coded OFDM Signal. **MUTA.** Vehicular Technology Conference. IEEE, 17 May 2004, vol. 4, 1911-1915 **[0006]**